NASA-CR-202528

## SUMMARY of RESEARCH

NASA Grant NAG 5-1069 *Ab-initio Models of the Solar Atmosphere – SMM*

PI: Lawrence S. Anderson
Ritter Astrophysical Research Center
The University of Toledo
Toledo, Ohio 43606

The purpose of the project was to use archival SMM data coupled with my non-LTE line-blanketed atmosphere code to analyze conditions in the quiet chromosphere and low transition region. The computer code I have been developing treats the radiative interactions of all atomic transitions in a fully nonLTE manner, coupling the radiative transfer equations for individual frequencies with global constraints of hydrostatic, radiative, and atomic statistical equilibrium. It contains explicit model ions for a limited number of light elements (atomic number < 22; for the solar study, H, He, C, Na, Mg, Al, Si, and Ca in ionization stages I–III), and a model iron atom onto which $10^7$ or so transitions of the elements Sc–Co have been mapped with appropriate abundance weighting.

During the report period, I continued previously started work with R. Grant Athay at the High Altitude Observatory, on a priori models of the solar atmosphere with prescribed non-radiative heating. By varying the depth dependence of the heating function, we were able to determine the thermostatic response of the chromosphere to changes in wave heating. One of the goals was to see how deep into the chromosphere the optically thin, composite radiative loss function is valid. We found that, at the densities of the solar chromosphere, the radiative loss function is sensitive to transfer effects and so not strictly a function of temperature at temperatures less than 7000 K, i.e. within the chromospheric plateau where hydrogen is mostly neutral. Above 7000 K, all heating functions are offset by the same radiative loss function. We found a radiative cooling rate for the chromospheric plateau of about 70 deg $s^{-1}$, which corresponds to a cooling time of about 100 s. This rapid cooling rate strongly favors heating by short-period waves. In addition, the mechanical heating rate required to maintain the chromospheric plateau at 6500 K was found to be about $10^{-14}$ ergs $s^{-1}$ $atom^{-1}$, which is consistent with the dissipation of saturated acoustic waves. The work on chromospheric equilibrium was published in three papers: Anderson and Athay (1989: *Ap.J.* **336**, 1089), Anderson (1989: *Ap.J.* **339**, 558), and Anderson and Athay (1989: *Ap.J.* **346**, 1010),

More directly related to the SMM project, I modified the code to handle the low transition region more economically. This part of the solar atmosphere presents particular modeling problems, because the gradients are steep. The position of the transition region in a common depth scale such as height or column mass is not known in advance of the model, which means one must use a prohibitive number of grid points to cover any likely result. However, if one chooses a relevant optical depth scale, such as the optical depth in H Lyman-$\alpha$, then the transition region can be treated on a fixed grid of modest proportion.

In addition to changing the model independent depth variable, I accumulated atomic data for the multitude of light-ion spectra visible in the SMM data, including C I-IV, N I,II, O I, Al II,III, Si I-IV, and S I,II, and prepared new model atoms for these ions. On a trip to NASA/GFSC, i searched the SMM archive catalog for relevant data. Unfortunately, most of the data was not directly relevant to the intended goal of the project, as it was acquired for quite different purposes. In addition, the limitations of the UVSP experiment precluded the observation of long spectral records of the same physical feature on the surface of the sun in a short time interval. In addition, while the compiled atlas of the quiet sun taken with slit 20 (entrance slit $1 \times 180$ arcsec, exit slit 0.01Å) represented a good average of the solar surface, the extreme inhomogeneity of the transition zone precludes extracting useful physical information from such averaged spectra. One of the later goals of the original proposal was to construct two-dimensional models in an attempt to unravel some of the problems associated with using averages or observations with non-resolving apertures, and/or studying the actual effects of geometrical structure on emergent spectra. This task turned out to be a very large effort; there is no obvious way of reducing the numerical code while maintaining the essential physics sufficiently to accommodate two-dimensional geometries in the available computers.

Lawrence S. Anderson